ORGANIZATION OF RESEARCH IN THE ADAPTATION OF THE GENERAL-PURPOSE TRACTOR*

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A project of research in any feature of mechanical farm equipment, such as the general-purpose tractor, usually requires a considerable expenditure of funds and of the time of personnel. It is, therefore, an investment, and as such, involves a risk. The prospect it has of returning dividends will depend primarily upon the degree to which it is sound, practical, and conservative. This in turn will depend upon the investigator, his scientific attitude, the depth of his purpose, and the conception he has of the problem and its requirements.

A project on the development of the tractor to adapt it to the requirements of general-purpose farming ought to commend itself in the prospect of results as well as in the desirability of the information sought. Such a project cannot return a dividend of information of permanent value unless it is properly organized to do so. If it cannot stand the test of searching scrutiny in this regard it is likely to be an undue risk.

There is probably no field of scientific endeavor in which the opportunity is greater for wasteful and misdirected effort than in that of research in mechanical farm equipment, and the tractor appears to be no exception in this regard. Numerous scrap piles of junked iron and the red ink of untold expenditures speak eloquently of lack of vision, inadequate fundamental conceptions, and lack of consideration for specific requirments in past undertakings of this character.

In the earlier days of experimenting with tractors the problem, as a whole, seemed simple and capable of solution by a few field trials and routine engineering computations. Further work showed, however, that the matter was considerably more complex than it appeared originally, and that investigations consisting solely of field tests of mechanical ideas, without the aid of further technical and scientific refinements in procedure, inevitably produced results of no finality. Now that the general-purpose tractor has appeared on the scene, the necessity for practically a new beginning with a revised vision, and improved technic, and a more detailed knowledge of requirements is apparent.

It is not the purpose to disparage elementary and practical investigations of tractors, for general testing and comparative field trials are the necessary preliminaries to better things, if they are considered as such. Without doubt there is frequently a place and a need for simple tests of tractors in the general-purpose class which are exploratory and designed to meet temporary requirements, but these should not be considered the means to an end. Such tests are not research in a true sense, and engineering investigators cannot afford at this pressing stage to exhaust themselves and their resources by such efforts, and

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of a definite and limited study in the order of its relative importance. As such, it should form an important integral part of a program of similar researches on the tractor which eventually will be coordinated into a broad basis for theory and practice in the design of tractors of the general-purpose class.

Thoughtful planning of such research will include also a consideration of the background of such empirical facts and information as are already available. Even though the research program under consideration proposes to establish new facts about specific features of the general-purpose tractor, such for example as steering, traction, or lateral stability, the conception of its logical organization lies in what already has been accomplished and especially in what definite things of a limited character this suggests.

In this connection much has been done by the agricultural experiment stations, the farm equipment manufacturers, and other public and private agencies to establish a background of empirical facts and information relating to the requirements of the tractor for general-purpose farming. Blind speculation is no longer necessary in the majority of instances to permit greater concentration of the objectives in research and the better formulation of the necessary ideas back of the development of features of the tractor to adapt it to the requirements of general-purpose farming.

It is recognized especially that the primary requirements of this machine are based upon its ability to perform the tillage, cultivation, and other power operations involved in the production of certain major row crops such as corn, cotton, and potatoes. Considerable field testing has been done with existing tractors on these crops to determine the degree of their present usefulness and to identify their deficiencies. The results of these tests point to numerous important individual features meriting separate, specific, and fundamental inquiry.

These features include the design of steering gear and drive and guide wheels and their equipment, traction and draft ability and efficiency, manner of power application, lateral and longitudinal stability, lateral and vertical clearance, design of hitches and implement attachments, overall lubrication, the efficiency of engine fuels and carburetion, air cleaning, engine cooling, and numerous other definite features. Each of these features contributes in its peculiar manner to the ability of the tractor to meet economically the established requirements of the crops concerned for tillage, cultivation, spraying, harvesting, and the like, under the range of soil, climatic and other conditions encountered in this type of farming, and the nature of such contribution should be thoroughly understood.

Each feature mentioned also has a background of empirical information upon which sound productive research can be built. For example, a study of the most economical and practical manner of power application by the general-purpose tractor to the different operations involved in row crop production, would include a consideration of power take-off and the like, regarding which considerable of a practical nature is already known. It has been shown that under favorable conditions only about half of the motor power of a tractor is delivered to the drawbar, and under unfavorable conditions this delivery is frequently reduced to as low as 25 per cent. It thus appears that the development of efficiency in the application of power must of necessity attach to specific operations and implements.

It also has been pointed out by public and private research agencies that the tractor has a low thermal efficiency. There has been much experimenting with fuels and motor lubrication in connection with the performance of definite power operations by the tractor which should serve as bases for specific fundamental researches of an important character.

The wide variations in soil types, especially in their tractive properties, has been the occasion for considerable experimenting with drive and guide wheel and hitch equipment. These have eliminated many theories and have tended to narrow the matter down to certain pertinent lines of inquiry. Experiments with horizontal clearance appear to have pointed to the necessity of clearing two or three rows of a major crop to permit the cultivation of at least four rows, thus defining the limits of development of this feature of the general-purpose tractor to meet the requirements of rather well established agronomic practices.

It would appear further that each instance of such research on features of the general-purpose tractor should be attached to a rather definite system and size of diversified farming and to a limited number of agronomic practices. It is hardly conceivable, in fact, that research of this character can be applied effectively to more than one set of conditions at a time. For example, some of the experiment stations have attempted to strike an average for vertical clearance of the general-purpose tractor to cover the requirements of major row crops generally. However, an analysis of the situation reveals numerous points of variation among row crops such as corn, cotton, potatoes, sorghum, and the like, which are inherent in the several established agronomic practices for their optimum production. Since the primary purpose of this research is to adapt the tractor to the requirements of the cropping practice, so far as is possible and practicable, and not vice versa, this would point to the necessity for considering the requirements of the crops individually in this connection.

It would appear also that each instance of such tractor research should be governed in its fundamental scientific aspects by the requirements of the specific operations involved in the production of the basic major row crop concerned. Preferably each separate inquiry should be aimed at settling one specifc point in question, such for example as steering or traction in cultivation, seeking to establish permanent basic values and principles of general applicability which can be used intelligently and profitably in tractor design and modified as the circumstances of general-purpose service require. The findings of several such specific inquiries should be calculated to blend into a practical understanding of these facts and a knowledge of their relationships, in the aggregate, establishing definite progress in the development and adaptation of the tractor to the different important features of general-purpose farming.

The organization of the procedure of a project of research on some specific feature of the general-purpose tractor should indicate at the outset the general line of attack and the technic and equipment to be employed. Naturally the details of procedure will be subject to revision from time to time, as the course of investigation depends on the progress results and what they indicate. Ascertaining what data are essential in solving the particular problem in hand, and devising means of securing them and testing them as to their adequacy and applicability are, therefore, important features in the organization of such research. Past experience has shown that these features include controlled laboratory researches, as well as verifying field tests. In recogni-

tion of this, several of the experiment stations have set up research equipment designed to isolate and control such specific features of the tractor as traction, lubrication, equilibrium, steering, and the like. Some foreign research institutions have likewise recognized the necessity at this stage of more profound studies of the tractor in its several details, and the Technical Agricultural Academy of Berlin, for example, has set up a laboratory for isolating and studying some of these details under controlled conditions. In fact, it appears that the basis of all such research on the tractor is the accumulation of evidence and its method of procedure is the means by which the needed evidence is secured. Therefore, the aim in each case should be, naturally, to so organize the procedure as to secure evidence that concerns the specific point at issue, that is as positive as possible, and is sufficiently extensive to enable critical analysis.

It is also essential therefore that the technical details of each problem under study be understood as fully as possible at the outset on the basis of what has gone before, and be developed as the work progresses. In tractor studies to meet general-purpose farming requirements there is, in fact, already some basis in the researches of others for judging the technical and scientific nature and content of certain problems at the time of organization. For example, the available knowledge of the fundamental physical principles of traction in certain types of soils would be pertinent to a study aimed at the development of general-purpose tractor drivewheels adapted to seedbed preparation and cultivation for corn on one of these soil types. Similarly the knowledge of the physical principles governing the movement of abrasive dusts in moving air currents would be pertinent to the study of air cleaning and lubrication in the adaptation of a general-purpose tractor motor to the cultivation of a crop in dusty regions. The available knowledge of the physical and mechanical properties of special metals such as high strength, light weight alloys, for example, may have considerable application in the development of tractor parts, which are subject to sudden heavy stresses, in attempts to adapt the general-purpose tractor to severe conditions of service such, for example, as plowing in the stony soils of Pennsylvania. All such previous technical evidence of a nature pertinent to the specific inquiry in progress may contribute in considerable measure to the solution of the problem, and therefore should be thoroughly mastered at the outset.

In this connection it is evident that successful research in the development of the tractor along general-purpose lines will depend to a large extent, not only on the advance of known engineering and agronomic principles, but on the advance of such related sciences as physics, physical chemistry, metallurgy, soil technology, and the like. In this as in other lines of inquiry regard must be had for the inevitable sequence in research necessary to unravel a problem. Results have sometimes been sought in such work which are unattainable because some branch of science essential to their solution has not been taken into account or has not produced the knowledge or supplied the ideas on which a working hypothesis could be framed. It will be recalled, for example, that an understanding of the elements of slippage in traction on certain soils and its correction waited a long time on the development of that feature of soil technology relating to the dynamics of stress distribution in those soils under tractive impulses. Other manifestations of the soil influencing the design of air cleaners and lubrication systems for tractors also were found to depend upon a recognition of the part played by those dust particles of colloidal size, thus introducing features of physical chemistry for consideration. The technic involved in the development of friction parts of tractors has been vastly improved by advances

in the knowledge of the physical principles governing the surface relationships of materials of construction, and improvements in the knowledge of metallurgy have played a part of no small importance in this.

Thus a knowledge of the progress of physical and biological sciences may make attainment in tractor development more possible, and hence the importance of breadth of vision and interest when investigating such a complex field. Advanced training in some of these related sciences for the agricultural engineer may be just what is needed to develop his imagination or expand his range of thinking. At least such broadening, stimulating influance promotes cooperation and coordination where desirable. It makes more apparent the advantage of greater system in tractor research and the logical following out of certain lines of advances through the various specialities involved.

In this connection the broad conception of the general-purpose tractor and its sphere of usefulness in farming would indicate that the organization and prosecution of research in its development are not functions of the agricultural engineer alone, but also will draw in the agricultural economist and agronomist on a close cooperative basis. It seems important at the outset, therefore, that full consideration be given the specific responsibilities of these three agricultural specialities in attaining the desired objective for the purpose of their effective coordination. This implies the arrangement of the engineering features of such research in relation to the economic and agronomic features, either through coordination or conscious participation in organized efforts to solve each particular problem involved in the development and rapid advancement of tractor knowledge.

With due appreciation of the advantage of specialization, it is apparent that the research specialist in mechanical farm equipment cannot afford to conceive his speciality too narrowly or limit his collateral interests too closely. Whether he is working on its problems independently or in cooperation, his work needs to be coordinated with other branches and features of agriculture which may be equally essential, and these considered in their respective relationships to complex problems such as those offered by the general-purpose tractor.

In addition, the research worker in tractors must cultivate originality and an inquiring and critically analytical frame of mind. He may be fortified by a vast and profound knowledge of science and technology, but unless he has developed a frame of mind which is capable of a systematic analysis and orderly synthesis of the elements of such a complex problem as that offered by the tractor, he is likely to become an assistant in such research instead of becoming the leader. The ability to think and reason in a systematic, orderly, and original manner, to analyze a problem into its essential features, and to apply scientific and technical knowledge where it will do the most good, eventually arriving at something definite and worth while about a specific thing, marks the distinction between the leader and the trailer in research in mechanical farm equipment.